Angle Lake Water Quality
Water Quality Monitoring Results for Water Year 2013

March 2014

King County

Department of Natural Resources and Parks
Water and Land Resources Division
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Water Quality Monitoring Results for Water Year 2013

Prepared for:
The City of SeaTac

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Table of Contents

Figures

Tables

OVERVIEW

The King County Lakes and Streams Monitoring (KCLSM) Group and its predecessor the Lake Stewardship Program have been working with volunteers on Angle Lake since 1994, although monitoring data collected by METRO goes back as far as the 1970s. In 2005, the City of SeaTac contracted with KCLSM to continue volunteer monitoring of Angle Lake. During the 2013 water year, four citizens volunteered their time to continue monitoring Angle Lake. The water quality data indicate that the lake continues to have low productivity, categorized as oligotrophic, with very good water quality.

Angle Lake is popular for fishing, boating, and swimming. The lake has a well-used public access boat ramp, and residents may want to monitor aquatic plants growing near shore to catch early infestations of Eurasian milfoil, Brazilian elodea or other noxious aquatic weeds, which are often transported by boats and boat trailers.

The discussion in this report focuses on the 2013 water year. Specific data used to generate the charts in this report can be downloaded from the King County Lake small lakes data website at:
http://your.kingcounty.gov/dnrp/wlr/water-resources/small-lakes/data/default.aspx

Data can also be provided in the form of excel files upon request.

Further introduction and a discussion of the philosophy of the volunteer lake monitoring program and the parameters measured can be found on-line at:

http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/waterres/smlakes/2006_Intro.pdf

1.0 WHAT WE MEASURE AND WHY

Measurements and parameters included in the small lakes monitoring program are discussed in this section to introduce them and to give context to the discussions of the data that follow.

Lake level is a relative measure of the water level that is measured daily using a staff plate installed on either a pole or a fixed height dock . These data can be used to look at the annual fluctuation of water levels in the lake, as well as response to increased water coming in due to storm events and the rate at which it drains. While most of the installed staff plates at lakes around the county are not surveyed to tie the data in with sea level, this could be done in the future to give actual elevations.

Daily **precipitation** is measured at the same time as lake water level in order to relate the lake level to inputs from the watershed. These data are collected either through a plastic rain gage provided by King County that can be emptied after reading each day or by a recording weather station if the volunteer chooses to purchase a reliable unit.

Level I volunteers measure Secchi depth and water temperature at a station in the middle of the lake weekly throughout the year. Level II volunteers measure 12 times between May and October when they collect water samples for laboratory analysis.

Secchi transparency is a common method used to assess and compare water clarity. It is a measure of the water depth at which a black and white disk disappears from view when lowered from the water surface. Level I volunteers measure Secchi depth and water temperature at a station in the middle of the lake weekly throughout the year. Level II volunteers measure 12 times between May and October when they collect water samples for laboratory analysis.

Water temperature is usually measured using an alcohol-based thermometer that holds a specific temperature long enough to allow the observer to read the value after retrieving the thermometer from the water.

Phosphorus and nitrogen are naturally occurring elements necessary for growth and reproduction in both plants and animals. However, many activities associated with residential development can increase these nutrients in water beyond natural levels. In lakes of the Puget Sound lowlands, phosphorus is often the nutrient in least supply, meaning that biological productivity is most often limited by the amount of available phosphorus. Increases in phosphorus can lead to more frequent and dense algae blooms – a nuisance to residents and lake users, and a potential safety threat if blooms become dominated by cyanobacteria (bluegreen algae) that can produce toxins.

Total phosphorus (TP) and **total nitrogen (TN)** are both measured every time the level II volunteers collect water at the 1m depth. More specific forms of nitrogen and phosphorus are measured twice during the sampling period, when water is collected from 3 depths at the station: 1 m, the middle depth of the water column, and 1 m from the lake bottom. These include nitrate-nitrite, ammonia, and soluble reactive phosphorus, and the data can be used to infer the amount of oxygen present in deep water, as well as the presence of internal loading of nutrients from the sediments back into the lake water.

The **ratio of total nitrogen to total phosphorus (N:P)** can be used to determine if nutrient conditions are favorable for the growth of cyanobacteria (bluegreen algae), which can negatively impact uses of the lake and potentially produce toxins. When N:P ratios are near or below 25, nitrogen is as likely to be the limiting nutrient as phosphorus. Certain cyanobacteria species may then be able to dominate the algal community due to their ability to take up nitrogen from air.

Chlorophyll-*a* concentrations indicate the abundance of phytoplankton in the lake. Although different species of algae contain varying amounts of chlorophyll, all algae use it in order to complete the photosynthetic pathway by which they store energy. For example, some cyanobacteria have other light-catching pigments and thus have relatively little chlorophyll compared to their biovolume.

Pheophytin is a product of chlorophyll decomposition and is generally measured along with chlorophyll as an indicator of how fresh or viable the phytoplankton in the sample are. Bottom sediments will contain a large amounts of pheophytin compared to chlorophyll, while actively-growing algae from surface waters will have very little pheophytin present.

A common method of tracking water quality trends in lakes is by calculating the **Trophic State Index (TSI)**, developed and first presented by Robert Carlson in a scientific paper dated 1977. TSI values predict the biological productivity of the lake based on three parameters that are easily measured: water clarity (Secchi), total phosphorus, and chlorophyll-*a.* The values are scaled from 0 to 100, which allow them to be used for comparisons of water quality over time and between lakes. If all of the operating assumptions about a lake ecosystem are met, the 3 TSI values should be very close together for a particular lake. When they are far apart in value, lake conditions and measurements should be examined to understand what special conditions exist at the lake or to evaluate the data for errors.

The Index relates to three commonly used categories of productivity:

- *oligotrophic* (low productivity, below 40 on the TSI scale - low in nutrient concentrations, small amount of algae growth);
- *mesotrophic* (moderate productivity, between 40 and 50 on TSI scale – moderate nutrient concentrations, moderate growth of algae growth); and
- *eutrophic* (high productivity, above 50 – high nutrient concentrations, high level of algae growth).

A lake may fall into any of these categories naturally, depending on the conditions in the watershed, climate characteristics, vegetation, and rock and soil types, as well as the shape and volume characteristics of the lake basin. Activities of people, such as land development, sanitary waste systems, and agricultural practices, can also increase productivity, which is known as “cultural eutrophication.”

2.0 PHYSICAL PARAMETERS

Methodical precipitation and water level records were compiled for the 2013 water year by Level I volunteers (Figure 1). Water levels followed a typical pattern for Puget Sound lowland lakes, with higher levels in the winter that decreased throughout spring and summer. Some sensitivity was shown to inputs from large rain events. Lake level rose earlier in the year compared to previous years, and remained fairly stable through the winter. Precipitation in April created a small peak in lake level for about three weeks. The lake ended the water year at a slightly lower level compared to 2011 and 2012, likely due to the warmer and drier climate experienced in the Pacific Northwest.

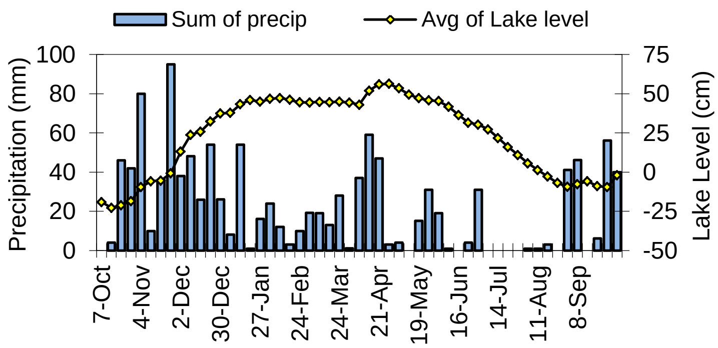

Figure 1. Weekly average lake level and accumulated precipitation for Angle Lake, water year 2013.

Average lake levels for 2013 and 2012 were nearly equal (23.8 and 24.0, respectively), and were higher than what monitoring records have typically shown over the period of measurement (Figure 2). Lake levels appear to be increasing overall since 2005, when the lowest average lake level was recorded. Recent years have been more similar to lake levels observed in the late 1990's through 2000.

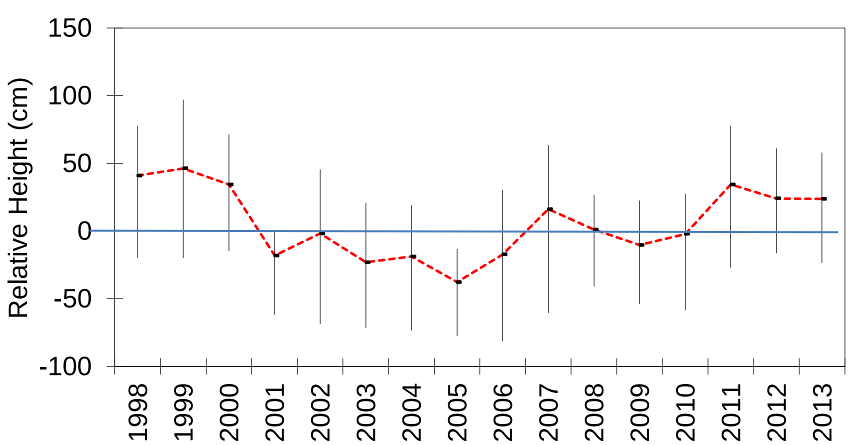

Figure 2. Average lake level for Angle Lake, water year 2013. Vertical lines represent the maximum and minimum for each water year.

Angle Lake Level I volunteers collected weekly temperature and Secchi transparency data throughout the 2013 water year. Additionally, a Level II volunteer collected Secchi transparency and temperature data twice monthly from early May through late October.

Level I Secchi measurements ranged between 3.6 and 8.1 meters, with an annual average of 5.8 meters and a summer average of 6.1 meters (Figure 3). Note that the Y-axis is traditionally reversed on Secchi charts to mimic looking into the water from the lake surface. Secchi transparency measured by the Level II volunteers was between 4.3 and 7.9 meters, with a summer average of 6.2 meters. Secchi measurements can easily vary between observers based on differences in vision, interpretation, and how close to the water surface the disk is being viewed. In this case, the Level I and Level II Secchi data were quite similar.

Angle Lake had the deepest average summer Secchi reading of the small lakes monitored in 2013. Secchi transparency in Angle Lake typically follows a pattern of higher clarity in late spring through summer, and decreased clarity in the fall and winter. Measurements from 2013 differed from more recent years in that transparency remained moderate to high for most of the year, and the typical pattern of fall lows and summer highs was not as pronounced, though it was present.

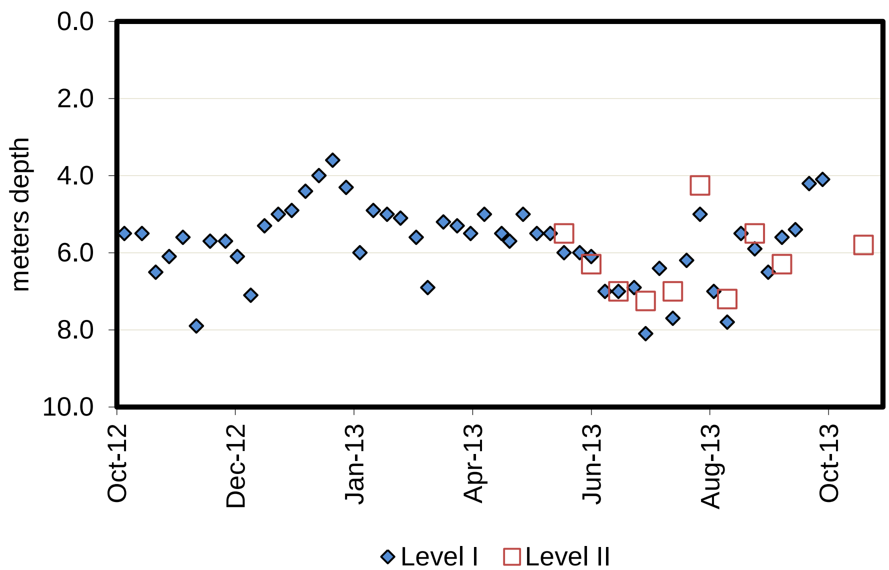

Figure 3. Secchi transparency for Angle Lake, water year 2013. Note inverted Y-axis.

Lake temperatures during the 2013 water year followed a pattern similar to other lakes in the region, with cooler temperatures in the winter and spring, summer maximum temperatures occurring in August, and temperatures cooling by late September (Figure 4). Level I temperature data ranged from 4.0°C to 24.5 °C over the year with an annual average of 13.7°C and a summer average of 20.6°C. Temperature patterns and ranges in 2013 were very similar to those from 2012.

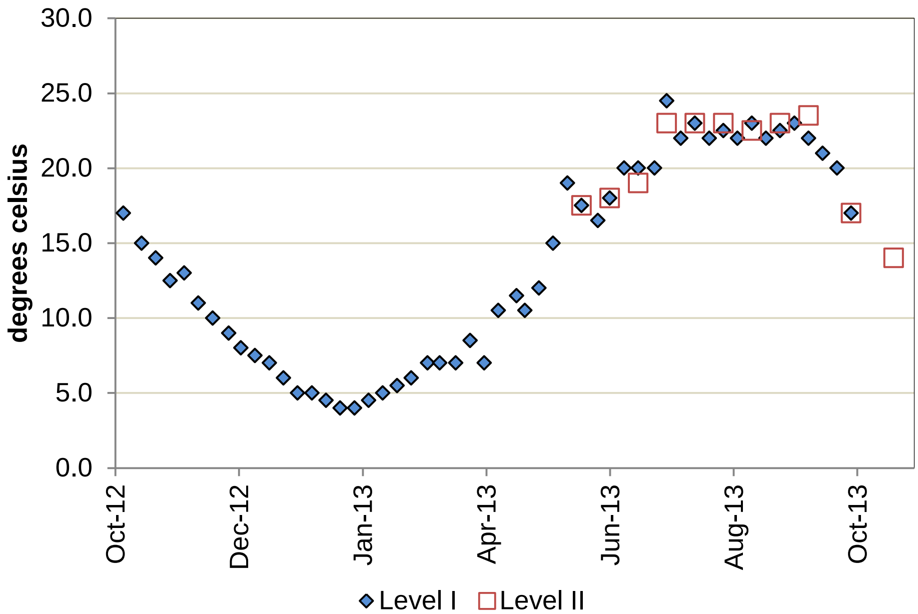

Figure 4. Temperature for Angle Lake, water year 2013.

The average summer temperature data collected by Level II volunteers in 2013 was slightly warmer than last year and was the highest recorded since the first sample season in 1997 (Figure 5). This increase reflects warmer, drier summer weather experienced in the Pacific Northwest in 2013. However, no long term trend towards increased water temperatures can be found over the whole period. A slow increase beginning in 2002 is balanced by a decline between 1997 and 2001.

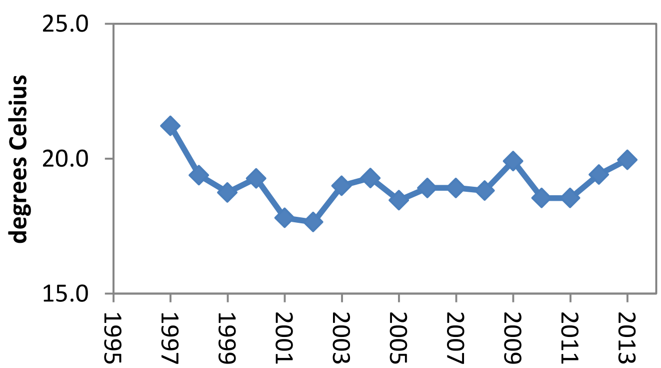

Figure 5. Average summer temperature for Angle Lake, 1997-2013.

3.0 NUTRIENT AND CHLOROPHYLL ANALYSIS

Samples to be analyzed for total phosphorus (TP) and total nitrogen (TN) were collected by Level II volunteers at a depth of one meter during the months of May through October. Samples from additional depths were collected in May and August.

Nutrient concentrations remained fairly stable throughout the monitoring period (Figure 6). Concentrations of both TP and TN were slightly higher at the beginning of the sample season, but remained essentially stable throughout the rest of the summer with a slight decline at the end of October. Levels of both TP and TN were similar to those from previous years.

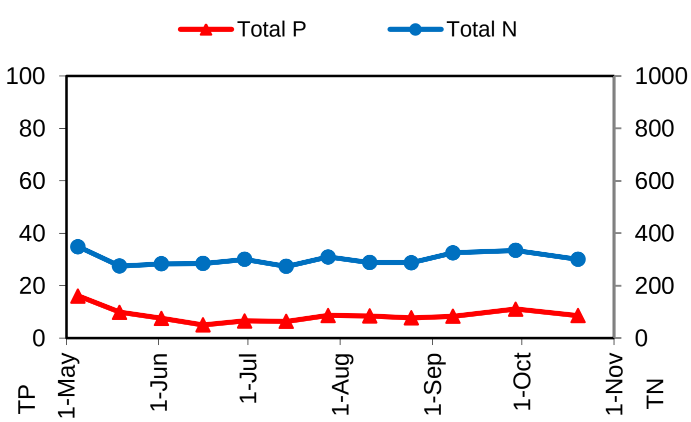

Figure 6. Angle Lake total phosphorus and total nitrogen in µg/L, May-Oct 2013.

The ratio of total nitrogen to total phosphorus in Angle Lake during the summer of 2013 ranged from 20.8 to 56.8, with an average ratio of 37.2 (Figure 7). The minimum ratio occurred in early May, which coincided with the highest nutrient levels of the summer. The ratio increased through July and remained above 25 for the duration of the summer, indicating that phosphorus was likely the limiting nutrient during most of the sampling season.

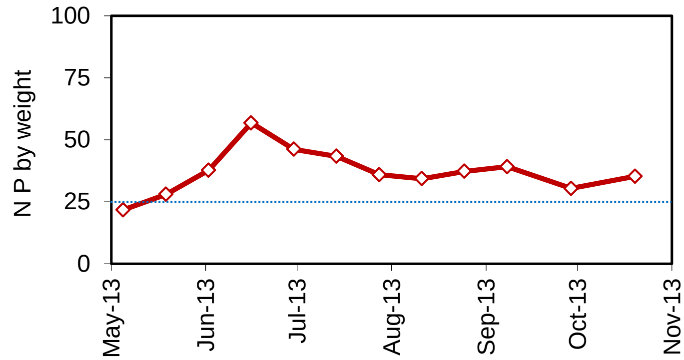

Figure 7. Angle Lake N:P ratios, May-October 2013.

Both the range and average N:P ratios for Angle Lake have increased since 2011, suggesting that the lake could be moving toward more pronounced phosphorus limitation in the summer months. However, a trend line drawn through the average since 1997 is flat, with a low correlation coefficient, so the increase over the last few years may just be due to interannual variability.

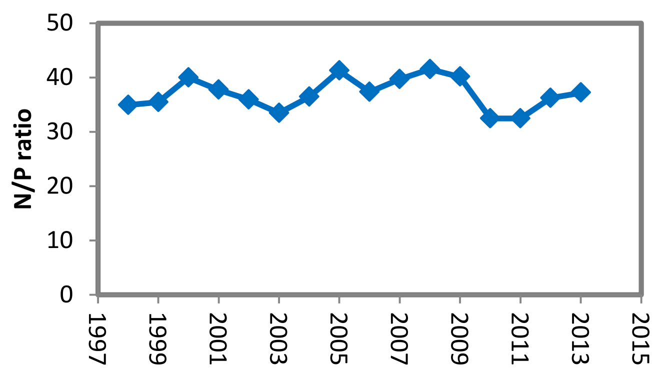

Figure 8. Angle Lake average summer N:P ratios since 1998.

Concentrations of chlorophyll-*a* in Angle Lake remained low for most of the sampling season, with a slight increase occurring in September through October (Figure 9). This autumn increase in chlorophyll-*a* is typical in many local lakes as algal populations increase in response to nutrients coming from the deep water with the onset of mixing of the water as temperatures cool. Pheophytin, which is a degradation product of chlorophyll-*a*, remained at or below detection limits throughout the summer.

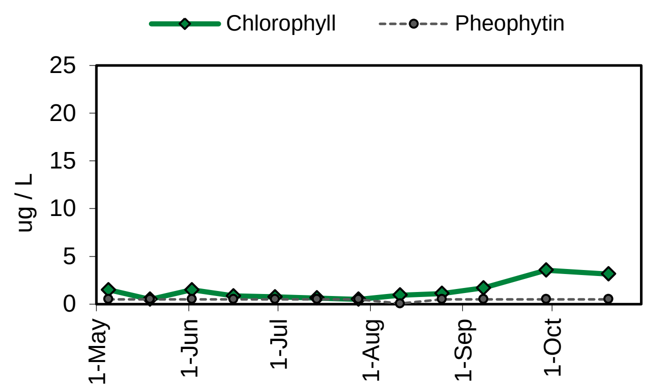

Figure 9. Chlorophyll and pheophytin concentrations for Angle Lake, May-October 2013.

4.0 WATER COLUMN PROFILES

Samples were collected by Level II volunteers at additional depths in May and again in August to create a profile of the water column in Angle Lake. Temperature data indicate that thermal stratification (temperature layering) was present by early summer and persisted through the second profile sampling event in late August (Table 1). The deeper water samples had significantly lower temperatures, as well as elevated levels of nutrients, which suggest that the hypolimnion (deep lake water below the temperature change) of Angle Lake became low in oxygen during the summer. Anoxia (lack of oxygen) in water facilitates the release of phosphorus from sediments, resulting in higher total phosphorus and orthophosphate (OPO4) values. Higher ammonia (NH3) concentrations in the deep water samples also indicate deep water anoxia.

Table 1. Angle Lake profile results. Secchi and Depth in meters. Temperature in degrees Celsius. Chlorophyll and Pheophytin in ug/L. Nitrogen, phosphorus, and alkalinity in mg /L. UV254 is in absorption units. Sample values below minimum detection level (MDL) are marked in bold, red font with the MDL value.

Lake name	Date	Secchi	Depth	DegC	Chlor-a	Pheo	Total N	NH3	Total P	OPO4	UV254	Total Alk
Angle	5/19/13	5.5	1	17.5	0.5	**0.5**	0.274	**0.005**	0.0098	**0.0020**	0.0426	13.5
Angle			8	13.0	7.3	**0.5**	0.335		0.0191			
Angle			15	8.0			0.559	0.236	0.0338	0.0077		
Angle	8/25/13	5.5	1	23.0	1.1	**0.5**	0.287	**0.005**	0.0077	**0.0010**	0.035	13.4
Angle			8	22.0	4.4	**0.5**	0.327		0.0144			
Angle			15	10.0			0.976	0.005	0.1140	0.0027		

Chlorophyll-*a* profile data indicate that algae are present throughout the water column, but at higher concentrations in mid-depth waters than at the surface. For both the May and August sample events, chlorophyll-*a* levels were higher at the eight meter depth than the one meter depth. These values suggest that enough light was reaching deeper waters to stimulate algal growth, or that algal species able to adapt to lower light levels were able to take advantage of higher nutrient concentrations.

UV254 is the wavelength at which most organic compounds absorb light and is used to measure the amount of organic compounds coloring lake water. The UV254 values in Angle Lake from the 2013 water year were similar to those from previous years. The low levels of UV254 indicate that the lake is fairly clear, with little coloration from dissolved organic substances. Total alkalinity in the lake was also similar to previous sample seasons. Alkalinity values were fairly low, showing that the lake water is soft and only lightly buffered against changes in pH, and thus more sensitive to acidification.

5.0 TROPHIC STATE INDEX RATINGS

In 2013 all three TSI values remained within the oligotrophic range (Figure 10). The chlorophyll-*a* TSI declined again from last water year, and was the lowest recorded TSI value, along with the TSI from 2008, since sampling began in 1994. Both chlorophyll-*a* TSI and total phosphorus TSI values have shown decreasing values in recent years, after prior increasing TSI values from 2008 - 2011. Secchi TSI also decreased, though only slightly, and has remained fairly stable since 2008, although before that year it appeared to be increasing steadily.

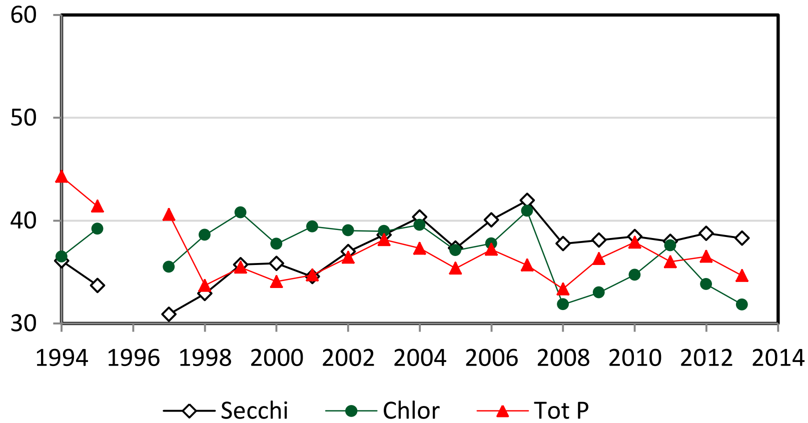

Figure 10. Angle Lake Trophic State Indicators, 1994-2013.

While the individual TSI values for Angle Lake have fluctuated up and down in the oligotrophic range over time, no clear trend of increase or decrease has been observed for any of the three values. Continued monitoring of Angle Lake will be beneficial in catching any changes that occur in the future, but currently the lake appears to have stable water quality in the summer months..

6.0 CONCLUSIONS AND RECOMMENDATIONS

Based on monitoring data, water quality in Angle Lake has fluctuated over the sampling years of 1994-2013, similar to the behavior of most aquatic systems in responding to multiple and diverse environmental variables. Measurements of physical and chemical parameters have shown both upward and downward variations from year to year.

Lake levels remained stable despite the warmer and drier climate experienced in 2012 and 2013. Additionally, lake levels rose earlier and remained stable for longer than in previous years. Secchi transparency exhibited a somewhat different trend compared to what has occurred in Angle Lake for the past few years. Typically a late season algae bloom will occur, creating a period of time during which Secchi depth becomes notably shallower. During the summer sample season chlorophyll-*a* levels did not indicate a fall bloom, and the seasonal decrease in Secchi transparency was not as pronounced.

Certain potential trends, such as that pertaining to temperature, could have negative impacts on Angle Lake. Increasing temperatures in the lake might have adverse effects on plants and animals, as well as water chemistry. While the temperature pattern over the course of the 2013 water year in Angle Lake was similar to that from previous years, average temperature during the summer sample season was the highest since 1997 (20.0°C and 21.2°C, respectively).

Nutrient and chlorophyll-*a* measurements continue to depict Angle Lake as oligotrophic, with low algal productivity, and likely phosphorus limitation. This is impressive considering the lake's location in reference to developed and urbanized areas, and therefore the potential for increased phosphorus inputs into the lake.

The long term monitoring that the volunteers at Angle Lake have performed since 1994 has created an impressive and useful dataset that reflects the water quality story of the lake. Continued monitoring will help build this dataset, increasing our understanding of how the lake reacts to changes in weather and other influences on the watershed. Continued monitoring of Angle Lake will allow for statistically robust determination of long term trends, as well as providing opportunities to identify potentially detrimental changes occurring in the lake